Report for 2002GA7B: RESERVOIR SHORELINE EROSION AND SEDIMENTATION ANALYSIS:

- Water Resources Research Institute Reports:
  - Sebnem, Elci and Paul A. Work, 2003, "Field Observations for Definition of Reservoir Shoreline Erosion and Sedimentation: Lake Hartwell, SC/GA," Georgia Water Resources Institute, Georgia Tech, Atlanta, GA., 48p.
- Other Publications:
  - Sebnem Elci and Paul A.Work, 2003. Numerical Modeling of Hydrodynamic Circulation and Cohesive Sediment Transport in Hartwell Lake, South Carolina/Georgia, USA. Contaminated Sediments: Characterisation, Evaluation, Mitigation/Restoration,Management Strategy Performance, ASTM STP 1442, J. Locat, R.Galvez-Cloutier, R.C. Chaney, and K. Demars, Eds., ASTM International, West Conshohocken, PA, 2003.

Report Follows:

Field Observations for Definition of

Reservoir Shoreline Erosion and Sedimentation:

Lake Hartwell, SC/GA

Şebnem Elçi and Paul A. Work

School of Civil and Environmental Engineering
Georgia Tech Regional Engineering Program
6001 Chatham Center Drive, Suite 350
Savannah, GA 31405

TECHNICAL REPORT

August 2003

Sponsored by:

Georgia Water Resources Institute

and

The U.S. Geological Survey

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. Abstract

A U.S. Environmental Protection Agency (EPA) “Superfund” site is located on a tributary to Hartwell Lake because of high concentrations of polychlorinated biphenyls (PCBs) in the lake sediments. In a previous study conducted by the authors, the fate of sediments introduced to the reservoir was investigated via numerical models of hydrodynamics and sediment transport (Elci and Work, 2002). The study described here involves surveying of the bathymetry of the lake and comparison of the results to the previous surveys to quantify 40 years of deposition.

The hydrodynamics of the lake were modeled using a numerical model and the results were presented in Elci and Work (2002). In this study, surface velocities are measured in the main pool of the lake to validate results of the numerical model.

With a total of 1516 erosion control structures along the lakeshores as of September 2002 (source: USACE Hartwell Office), shoreline erosion has been a significant problem for Hartwell Lake. Elci and Work (2002) developed a methodology for predicting shoreline erosion. In this study, two peninsulas with large fetches are surveyed to provide data for the shoreline erosion prediction methodology.

This report addresses the field data collection and analysis in Hartwell Lake, SC/GA. The primary goals of the study are:

1. Survey bathymetry of different transects in the main pool and compare to old surveys conducted by the U.S. Army Corps of Engineers.
2. Measure surface velocities along different transects.
3. Survey shorelines of the lake.

2. Introduction

This report describes the field data collection and analysis in Hartwell Lake, a U.S. Army Corps of Engineers (USACE) reservoir, located on the Savannah River, between Anderson, South Carolina, and Hartwell, Georgia, USA (Figure 1). The reservoir was built between 1955 and 1963, with joint goals of flood control, power production, water supply, and recreation (Elci and Work, 2002). High concentrations of polychlorinated biphenyls (PCBs) have been found in the lake and in Twelve-Mile Creek, a tributary, resulting from the operation of a capacitor manufacturing facility in the Twelve Mile Creek Watershed from 1955-1976 (EPA, 1991). In a previous project funded by the

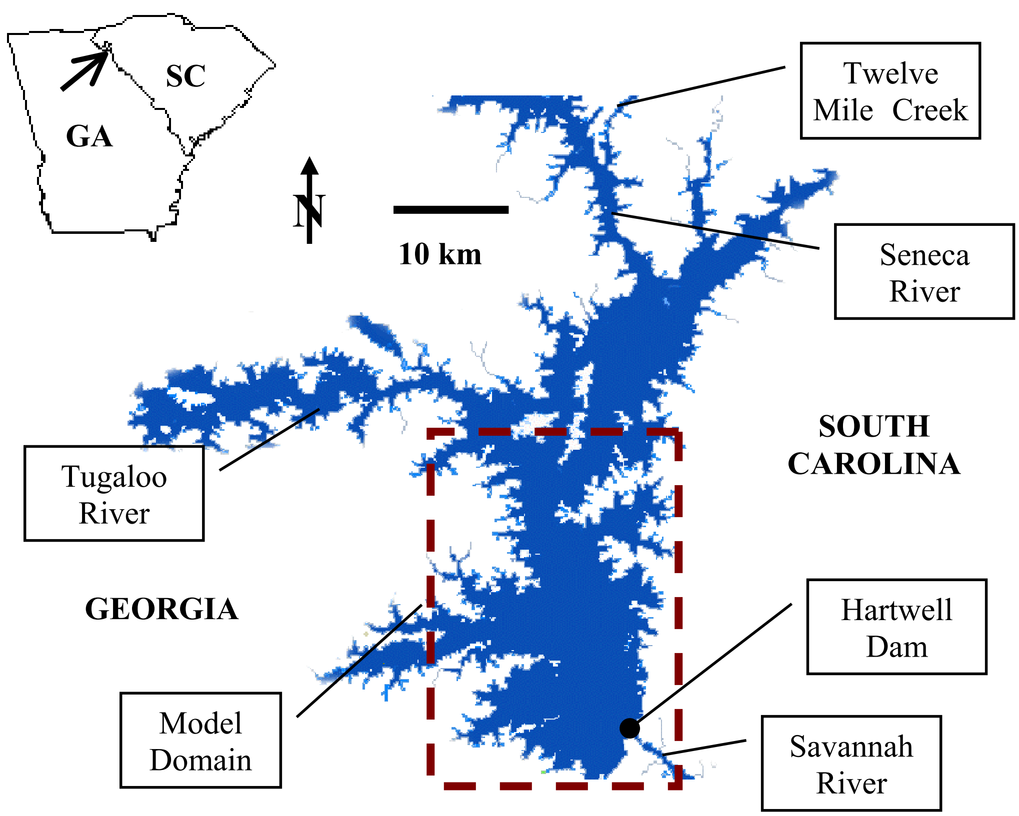


Figure 1. Map of study site. Dashed box shows the region within the main pool of the lake that was modeled (numerically) to describe the water circulation and sediment deposition patterns.

South Carolina Water Resources Center (SCWRC), the hydrodynamic circulation and sedimentation in the main pool of Hartwell Lake were investigated via 3-D numerical modeling of hydrodynamics and sediment transport (Elci and Work, 2002). For this purpose the Environmental Fluid Dynamics Code (EFDC) developed by Hamrick (1996) was applied to Hartwell Lake to simulate hydrodynamic processes in the lake. The main objective of the field data collection effort described in this report is to obtain data for validation of the results of the hydrodynamic model. This effort also yielded bathymetric survey data to quantify sediment deposition in the main pool of the lake, since the lake was last surveyed in 1970's.

Hartwell Lake has a shoreline length of 1548 km, and erosion of lakeshores has been a significant problem for homeowners. As of September 2002, there were 1123 permitted riprap installations, and 393 permitted retaining walls, for a total of 1516 erosion control structures along the lakeshores (source: USACE Hartwell Office), an indication of the magnitude of the erosion problem. Another objective realized in the previous project was to develop a methodology for estimating shoreline erosion rates. The study described in this report also resulted in new shoreline data for calibrating and testing the erosion prediction methodology.

The field data were collected February 10-14, 2003. Throughout the week, very strong winds (more than 4 times the historical average) from the southwest were observed (Figure 2). The mean water level was 199.33 m.

Hartwell Lake is an example of a warm monomictic lake, which is vertically mixed from December to March, and thermally stratified to varying degrees between April and

November. Figure 3 shows a temperature profile measured at a station near the dam in February 2002.

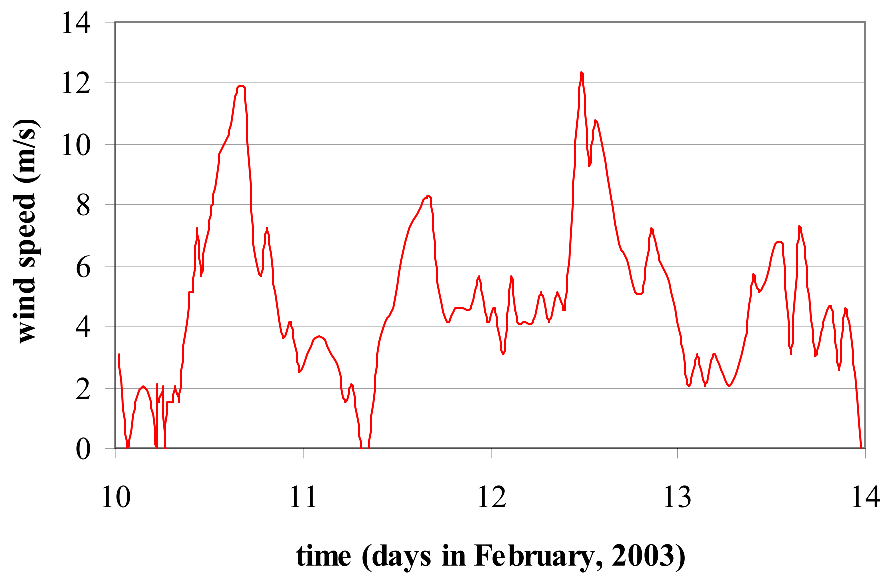


Figure 2. Hourly wind speed data obtained from Anderson County Airport, SC during field measurement campaign.

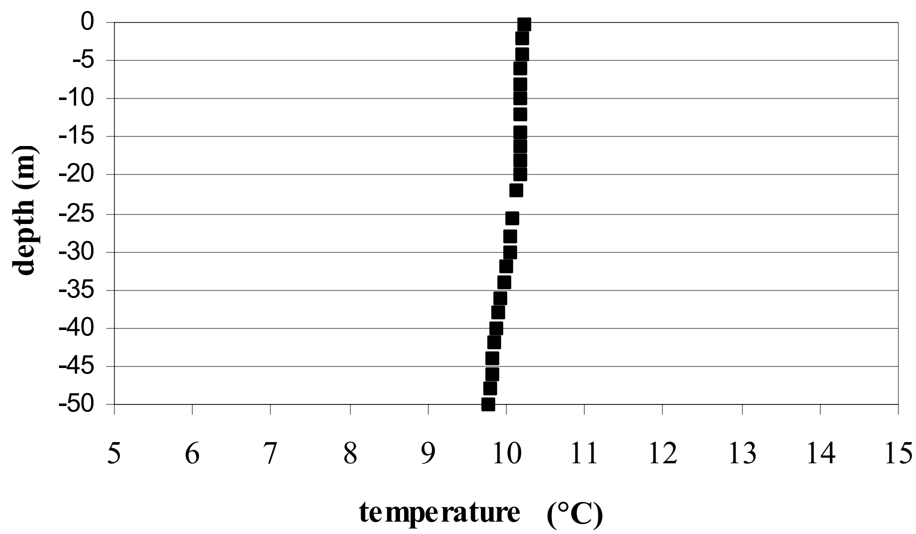


Figure 3. Measured temperature profiles at a station near dam in February 2002.

Field data collection and analysis described in this report is a continuation project to provide data to validate the results of the previous project funded by South Carolina Water Resources Center (SCWRC). For details and findings of the previous project, the reader is referred to the technical report submitted to the SCWRC by the authors (Elci and Work, 2002). In this report, the techniques to collect, bathymetric, velocity and shoreline position data are first described. Then, the results from topographic surveys conducted by USACE in the past, and the new bathymetric surveys are compared. Next, a summary of new velocity data is presented. Finally, shoreline data are presented. In the conclusion of this report, benefits associated with these two projects are stated.

3. Data Collection

This section discusses the techniques applied to collect bathymetric, velocity and shoreline position data in Hartwell Lake, SC/GA. Bathymetry data collected along several transects were compared to old surveys to quantify 40 years of deposition in the lake. Surface velocities were measured to validate the results of a numerical model used previously for simulation of the hydrodynamics in the lake. Two peninsulas along the shoreline of the lake were surveyed to provide data for validating a shoreline erosion prediction methodology previously developed by the authors.

3.1. Bathymetric Survey Data

Two sources of bathymetric data are available for the lake: data collected by the U.S. Army Corps of Engineers (USACE) in the past, and new data collected by the authors in February 2003.

i) Corps of Engineers data

Three surveys of different transects across the lake were conducted by the USACE; a topographic survey in 1959 before completion of the dam in 1963, a bathymetric survey in 1963 and another in 1973. Although the 1959 survey included several cross sections within the main pool of the reservoir, surveys from both 1963 and 1973 were available mostly for the upstream region of the main pool on the Tugaloo and Seneca Rivers. A map showing the transects surveyed by USACE is given in Figure 4. Projection, datum and mean water level data for the historical surveys are given in Table 1.

The historical surveys used the method of triangulation from known benchmarks. Concrete monuments at locations along the future shoreline were established and land was surveyed by creating a loop with level lines and turning points. The surveys were

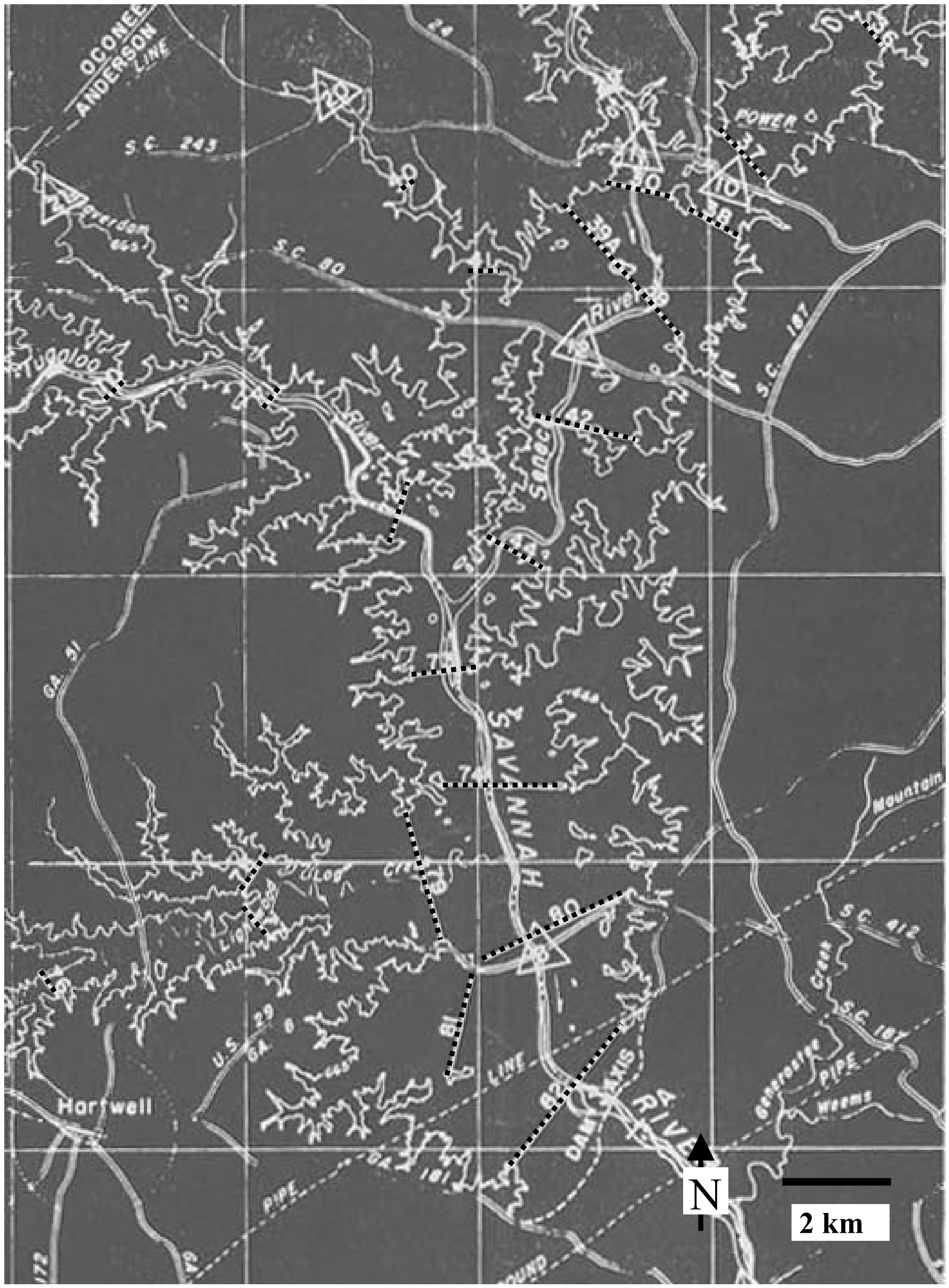


Figure 4. A map showing the transects surveyed by USACE (source: USACE, Savannah District).

Table 1. Projection, datum and mean water level data for the previous surveys.

Survey year	Mean water level	Datum	Projection
1959	-	1927 North American Datum	Plane Coordinate System based on Georgia East Zone and South Carolina North Zone
1963	200.59		
1973	201.06		

done with an accuracy of ±1.2 cm in the vertical (Jason Ward, USACE, Savannah District, pers. comm.).

The USACE provided the survey data in an analog, graphical format for each transect, with elevations plotted versus horizontal distance from the starting point of the transect. Transect 74 is shown in Figure 5 as an example. Locations of benchmarks were not precisely described. Other available transects are given in Appendix.

ArcView's Digitize extension was used for conversion of graphs to digital format. Digitizing errors are estimated as ±15 cm in vertical and ±1 m in horizontal prototype scale.

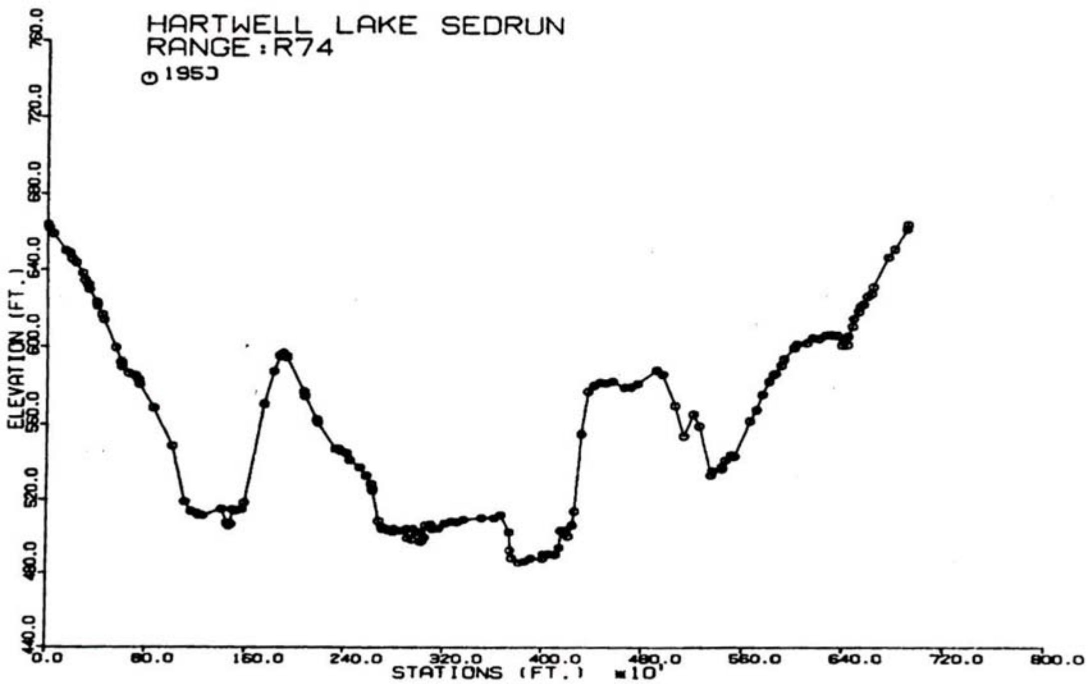


Figure 5. Bathymetric survey data from 1959 provided by USACE for transect 74.

ii) New data

A survey system shown in Figure 6 was used to collect hydrographic survey data. The survey system was mounted on a Boston Whaler 17 foot fiberglass boat. Depth data were provided by a dual frequency depth measuring system (high frequency 200 kHz, low frequency 30kHz), Digital Echo Sounder Ceestar, manufactured by Bruttour Int. Figure 7 shows the mounting of the depth sounder. Digital depth data were directly logged to a laptop computer equipped with Coastal Oceanographic's HYPACK Hydrographic Survey Software. Data were output and stored at a rate of 6 soundings / sec.

Figure 6. Boat used for data collection

Figure 7. Over the side mounting for dual frequency depth sounder.

Echo sounders in general determine the distance between a transducer, that converts electrical energy to sound, and dense objects such as fish or a seabed. An ultrasonic wave is transmitted through water, and as the sound wave strikes an object, it is reflected back toward the source and received by the transducer. The speed of the ultrasonic wave varies with temperature and is 1447 m/s for 10 °C fresh water. The depth of the object is then calculated by the time difference between transmission of sound wave and the reception of the reflected sound.

Dual frequency echo sounders are commonly employed in areas where soft sediments are present. High and low frequency transducers have different characteristics. High frequency transducers transmit a signal of 200 kHz and it is more directional with a smaller beam angle (Figure 8). Low frequency transducers transmit a signal of 30 kHz that penetrates to a greater depth with a wider beam angle covering a greater sea bottom area. However a sharper focus of the transmitted energy is achieved at higher frequencies. Low frequency depth measurement can be used only if the slope of the bottom is low and there are no structures nearby.

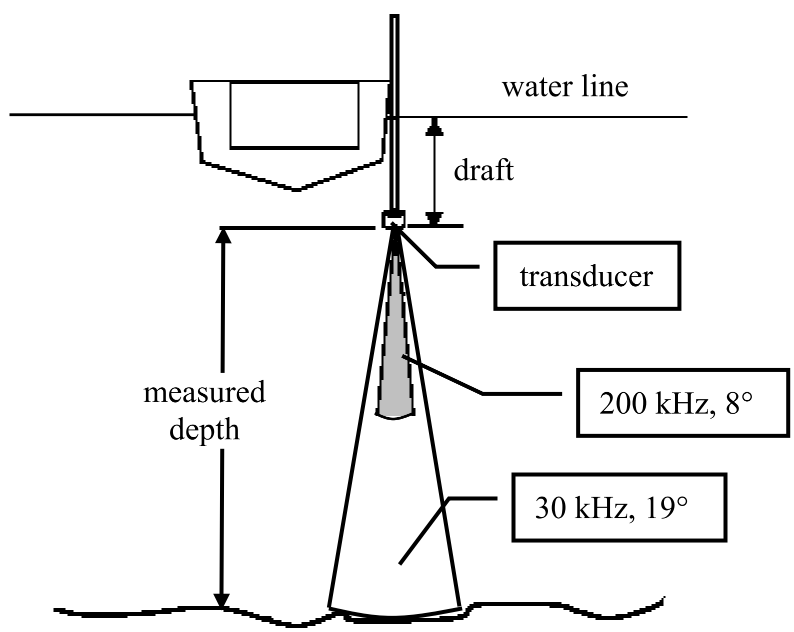


Figure 8. Representation of high and low frequency transducers (adapted from Bruttour, 2003).

The Corps of Engineers recommends that for bathymetric surveys, a horizontal positioning error should be less than 5 meters. Horizontal positional accuracy is not critical for a reservoir sedimentation survey (USACE, 2002).

The transects previously surveyed by USACE in the main pool of the reservoir were marked on the lake map provided by Mapsource software of Garmin (Figure 9). The coordinates of the two ends of transects were obtained using Mapsource software and were uploaded to the GPS as waypoints which were used to navigate during the surveys.

During the surveying of the transects shown on Figure 9, the draft for the high and low frequency transducers were 28 ± 1 cm and 20 ± 1 cm respectively. The measurements were then corrected to account for the draft. Another correction was made because of the projection and datum used in historical surveys was different then the current survey. Conversion of depth data measured using 1927 North American Datum (NAD 27) projected by the Plane Coordinate System to 1983 North American Datum (NAD 83) projected by the Universal Transverse Mercator (UTM) were made by Corpscon program provided by USACE.

The manufacturer's rated accuracy for the depth sounder is 0.01 meter, however the prior measurements during the testing of the equipment indicated 0.10 meter accuracy. The sources of errors in old and current surveys add up to ± 27 cm and are summarized in Table 2.

Table 2. The error sources in old and current surveys.

Source	Magnitude
Depth measurement errors	± 10 cm
Draft measurement errors	± 1 cm
Errors in old survey	± 1.2 cm
Digitizing errors	± 15 cm

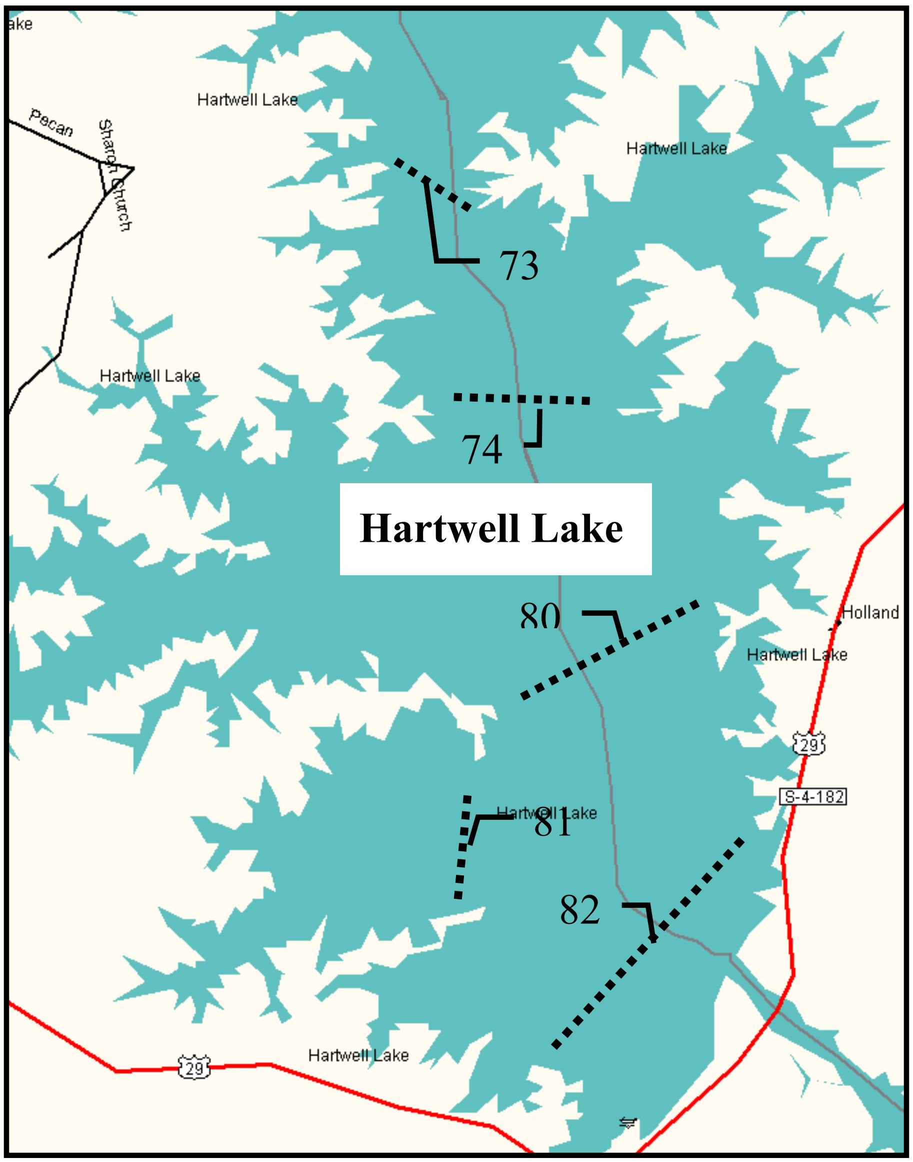


Figure 9. Transects surveyed in Hartwell Lake.

3.2. Velocity Data

Velocity measurements are made using a 1200 kHz Workhorse Sentinel Acoustic Doppler Current Profiler (ADCP) developed by RD Instruments (Figure 10). It is designed for measuring real time current profiles in ocean, near shore, harbors and lake regions. An ADCP estimates horizontal and vertical velocity as a function of depth by using the Doppler effect to measure the relative velocity between the instrument and scatterers in the ocean. The Doppler effect is a change in the observed sound frequency that results from relative motion toward or away from the sound source.

Measurement of velocities by the ADCP is described in the user's manual as follows: “An ADCP utilizes the Doppler effect by transmitting sound at a fixed frequency and listening to echoes returning from sound scatterers in the water. These sound scatterers are small particles or plankton that reflect the sound back to the ADCP. Three acoustic beams in different directions are the minimal requirement for measuring the three velocity components. A fourth beam adds redundancy and an error estimate. The ADCP

Figure 10. Over the side mounting for ADCP.

transmits a ping from each transducer element roughly once per second. The echo arrives back at the instrument over an extended period, with echoes from shallow depths arriving sooner than those from greater distances. Profiles are produced by range-gating the echo signal, which means the echo is broken into successive segments called depth bins corresponding to successively deeper depth ranges. The operator configures the length of each depth bin and the transmit pulse, which determines the degree of averaging in the vertical, depending on whether one is interested more in vertical resolution or profile penetration. The noisy velocity estimates from each ping are vector-averaged into user specified ensembles." For specifics of the instrument capabilities and configuration options the reader is referred to the user's manual (RD Instruments, 2001).

The navigation information provided by a Global Positioning System (GPS) receiver is integrated and used to obtain the relative velocities to the earth's reference frame. Data are averaged to reduce the measurement uncertainty. Velocity uncertainty includes two kinds of errors: random error and bias. Averaging reduces random error. The size of the random error depends on ADCP frequency, depth cell size, number of pings averaged, and beam geometry. External factors such as turbulence, internal waves and ADCP motion also influence error. Bias error depends on temperature, mean current speed, signal/noise ratio, and beam geometry.

For quantification of this bias error several tests were performed in a 2.5 meter deep swimming pool prior to the field trip. The ADCP was placed in the middle of the pool bottom looking upwards. The pump of the pool was turned on and off so that the velocity magnitude and direction uncertainty could be investigated. Data were averaged every 10 minutes. Depth of each cell (bin) was selected as 10 cm. Figure 11 shows the measured velocity magnitude plotted versus ensemble for bin numbers 5 and 10, corresponding to 1.16 m and 1.66 m depths. Figure 12 shows the measured direction of the currents plotted versus ensemble. The pump was turned off after 30 minutes and turned on again after 460 minutes. When the water was turned off the average noise levels observed were 1.4 cm/s at 1.16 m water depth, and 1.2 cm/s at 1.66 m water depth. The noise level of the ADCP

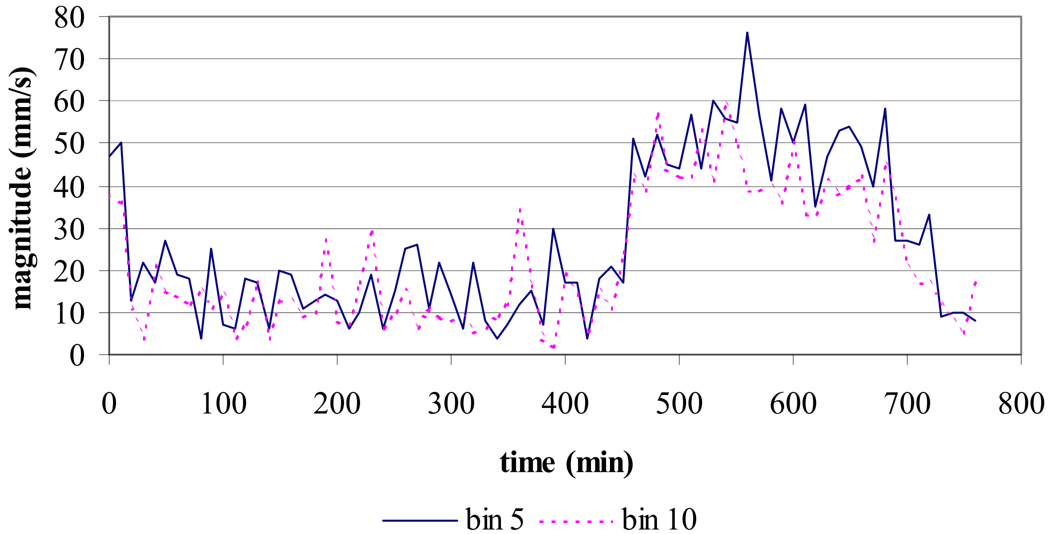


Figure 11. Measured velocity magnitude during pool tests.

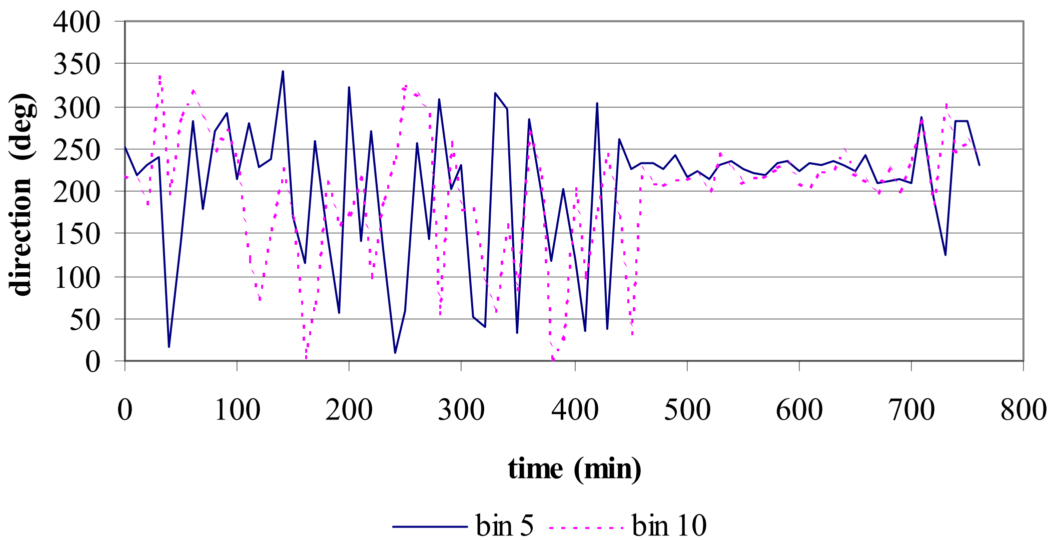


Figure 12. Measured velocity direction during pool tests.

is determined as ± 1.4 cm/s based on the pool tests.

During the collection of data in Hartwell Lake, velocity data were collected in self-contained deployment, and stored internally every 30 seconds with a bin size of 1 meter. The velocities had to be corrected for boat speed since the measurements were made while the boat was moving.

There are two options for correcting boat speed during the measurements: i) bottom-track, ii) GPS options. The primary function of bottom-track is to measure the ADCP's speed-over-bottom and detected range-to-bottom. The absolute water velocity is calculated by subtracting the boat's velocity from the relative velocity measured by the ADCP, where the cross-sectional area of the transect has to be estimated for the discharge calculation. However when the bottom is out of range or if there is a very heavy layer of suspended sediment moving along with the flow, the ADCP can falsely detect the bottom in the moving suspended sediment layer, resulting in biased measurements.

In both cases, it is necessary to have an external means for estimating the boat's velocity. GPS is used to estimate the boat's velocity while underway. During the velocity measurements in Hartwell Lake, the velocities are corrected for boat speed according to the GPS.

The errors associated with the GPS were quantified with a simple test. The GPS was left to record coordinates at a fixed location for 20 minutes, and the recorded coordinates are plotted. The average horizontal error was 1 m and the errors evolved gradually, between two consequent recordings errors were lower than the average (Figure 13). In other words errors were biased in time, decreasing the uncertainty in boat speed. This observation suggests that when the boat moves with 3.3 m/s speed in 30 seconds it covers

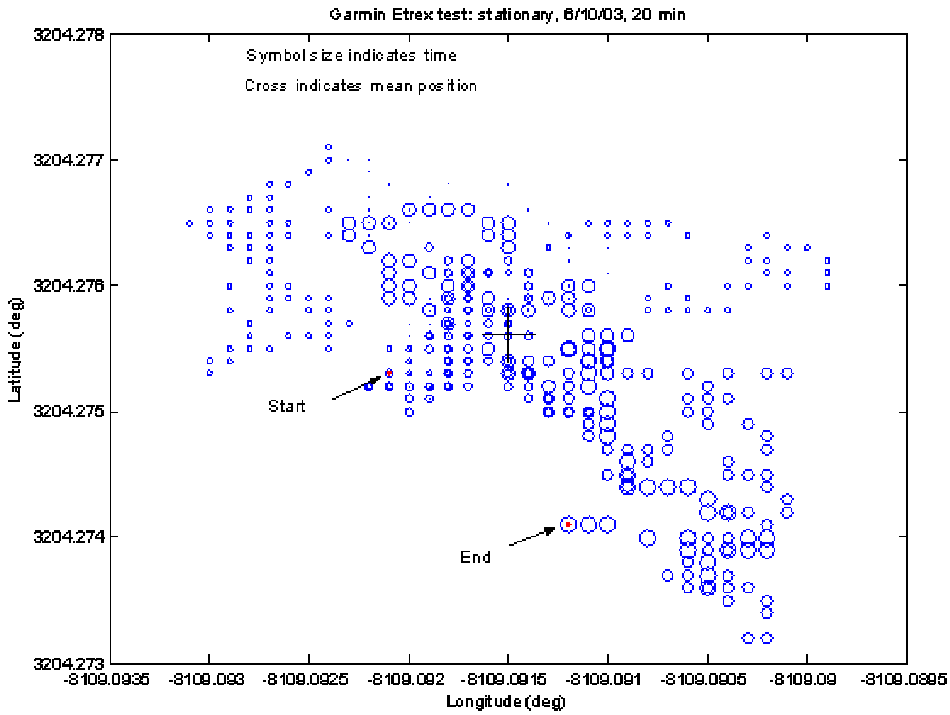


Figure 13. Evolution of Garmin Etrex errors at a fixed location. Symbol size indicates time.

100 m of distance. An average of 1 m of error between two readings causes ± 6 cm/s error in boat and water current speed.

The instrument configuration used for the velocity measurements is given in Table 3. Some of the configuration details can be summarized as follows: WF blanks out bad data close to the transducer head. WN sets the number of depth cells over which the Workhorse collects data. TP sets the minimum time between pings. It was set to 20 (hundredths of seconds). WP sets the number of pings to average in each data ensemble. WP = 150 corresponds to averaging time of 30 seconds. WL is used to lower the effects of transducer motion by averaging the velocities of a column of water and subtracting the average velocity from each of the depth cell velocities. WM selects the application – dependent profiling mode used by the ADCP. Dynamic sea state mode was selected for this application. EA is a heading alignment angle and it corrects for physical misalignment between Beam 3 and the heading reference. EB is the heading angle that counteracts the electrical bias and it corrects electrical/magnetic bias between ADCP heading value and the heading reference. EX sets the coordinate transformation. Earth coordinates were selected, however for the coordinate transformation to work properly, heading alignment and heading bias must be set correctly. Since they were not set properly correction for the velocity data direction was required. EZ selects the source of environmental sensor data. It was selected that ADCP uses data from appropriate sensor.

Table 3. Configuration of ADCP used for data collection.

Orientation	Down
Beam Angle	20 Degrees
Blank (WF)	0.44 m
Min Pgood (WG)	0
Ref Layer (WL)	1, 5 first bin, last bin
Mode (WM)	1
Bins (WN)	17
Pings/Ens (WP)	150 (30 seconds)
Bin Size (WS)	1 m
Head Align (EA)	0.00 degrees
Head Bias (EB)	0.00 degrees
Coordinate Transformation (EX)	11111
Sensor Source (EZ)	1111111
Time/Ping (TP)	00:00.20

Correction is required to account for the discrepancy between true north and magnetic north. True north is defined by the axis of rotation of the earth. Magnetic north, at the other hand, is defined by the earth's magnetism caused by the flow of electrons in its fluid metallic core in motion. The earth's magnetic poles are mobile and therefore magnetic north varies over time, as well as from place to place, on earth. The ADCP uses the compass to determine magnetic heading, and GPS uses true north. For the duration of the field trip, and location of Hartwell Lake this difference was - 5 degrees and 22 minutes (Figure 14). The velocities were corrected by adding this difference to direction.

Due to the rough weather conditions during the period of field trip, successful measurements were mostly made on the west side of the lake. The transects where the velocities were measured are shown in Figure 15.

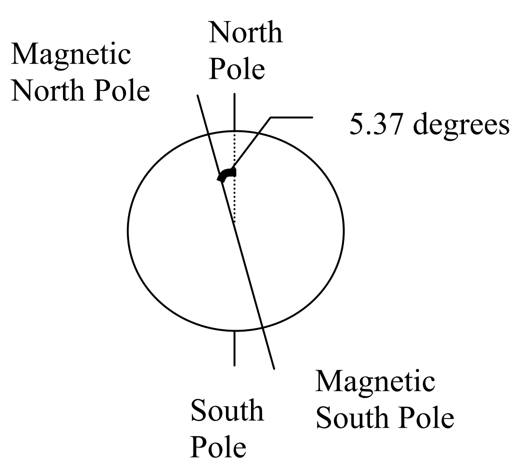


Figure 14. Representation of true north with respect to magnetic north on February 12th 2003, at Hartwell Lake.

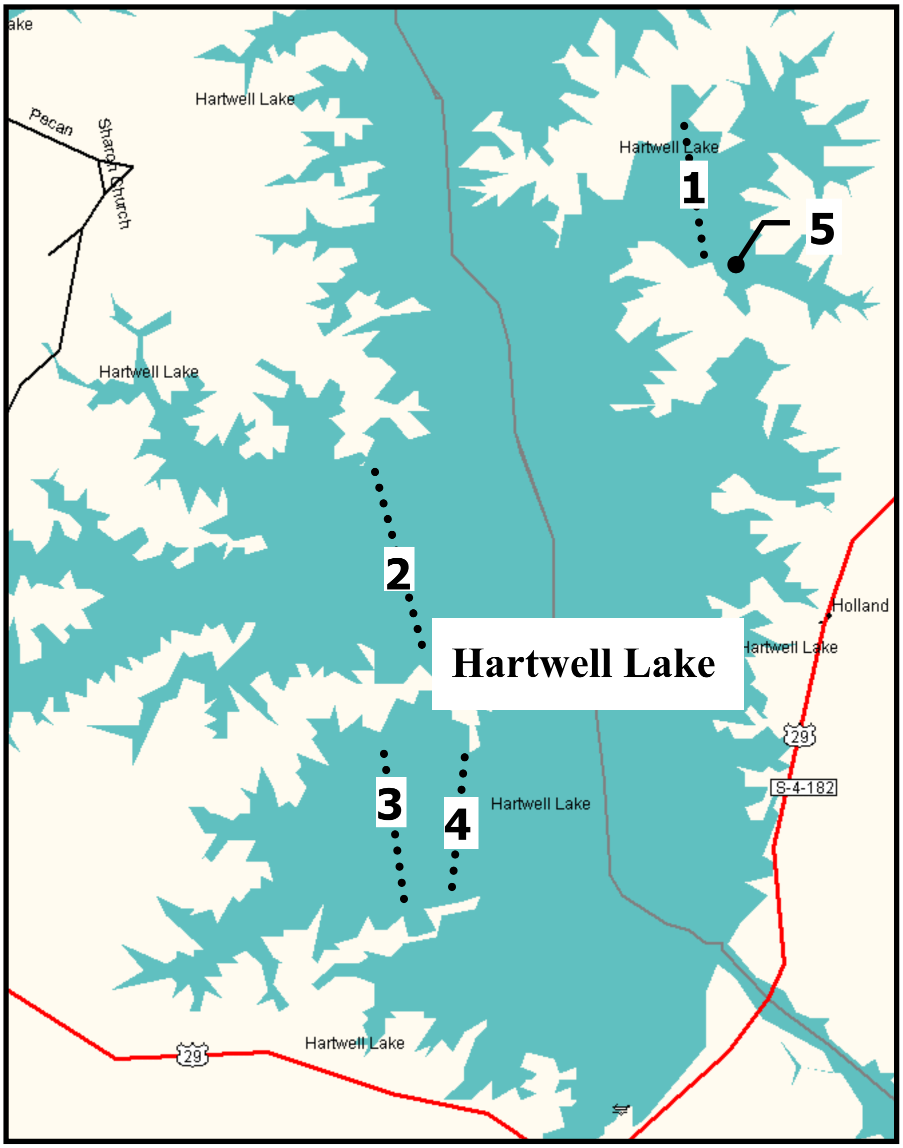


Figure 15. Transects where the current velocity vectors are measured by ADCP.

3.3. Shoreline Position Data

Horizontal positioning data defining shoreline positions were supplied using an Ashtech Z-12 model differential global positioning system (GPS). This instrument was developed for geodesy, surveying and precise navigation applications and tracks up to 12 satellites. This system utilizes the GPS measurement data from a stationary GPS receiver at a known site (base station) to correct for errors in the measurement data of a GPS receiver at an unknown site (remote station). For real time differential measurement, the data are transferred from the base station to rover station via a radio link. Precision is documented as ±(5mm + 1ppm) for static GPS, ±(10mm + 1ppm) for kinematic GPS, and cm-dm accuracies for baselines <100km for kinematic (resolved ambiguities). GPS accuracy depends on many factors, with the primary errors being due to satellite related errors, receiver related errors, and signal propagation errors (Work et al. 1998).

The base station was set at a National Geodetic Survey monumented benchmark located at Sadlers Creek State Park, in Anderson County, SC (Table 4, Figure 16).

Table 4. Details of benchmark used for base station.

Name, Designation	ED3754, Sadlers Creek
Coordinates	N 34 25.633 W 82 49.859
Altitude	211.53 m

Figure 16. Base station set up at Sadlers Creek State Park.

The Sadlers Creek and Longpoint Peninsulas shown in Figure 17 were surveyed. These two locations were selected since they are exposed to greater fetches which would likely result in greater erosion problems. In fact during the survey of the peninsulas it was observed that most of the shores along both peninsulas are protected by erosion control structures such as ripraps and revetments.

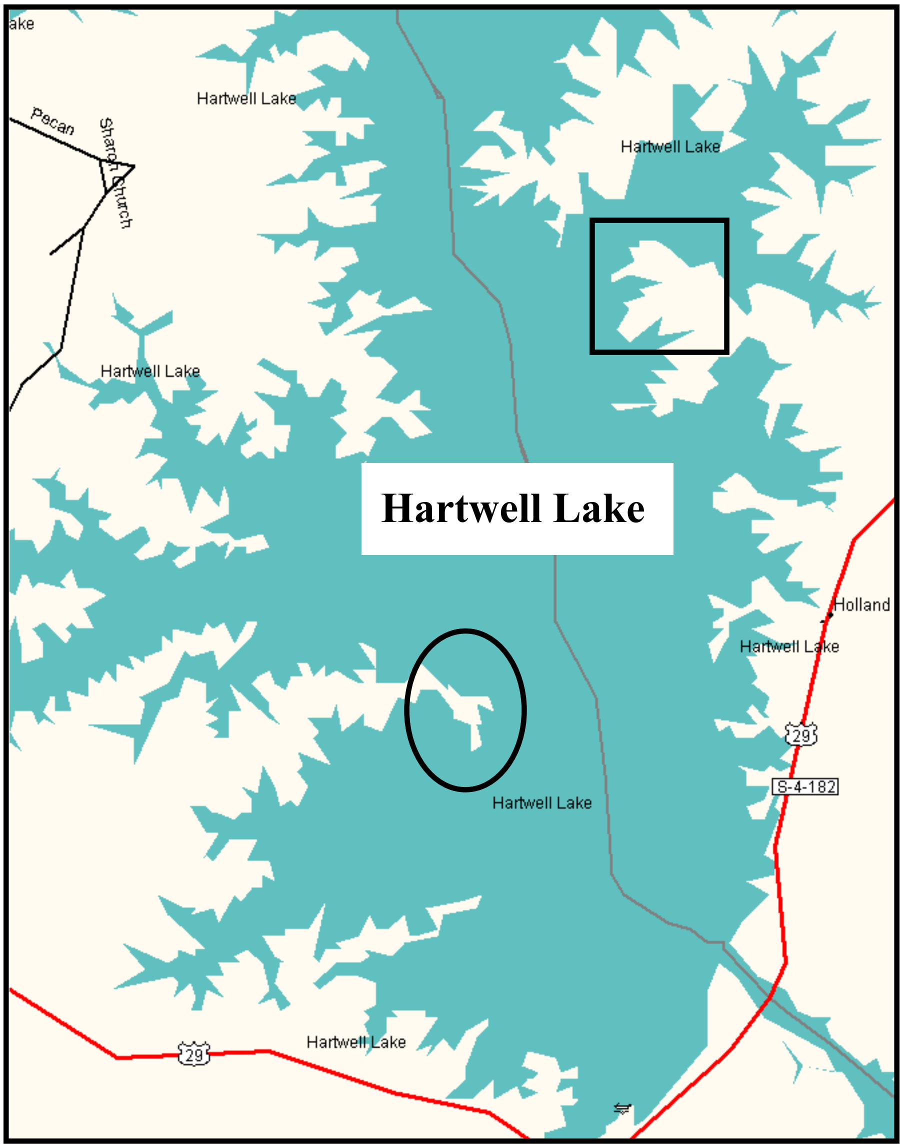


Figure 17. Peninsulas surveyed along the shores of Hartwell Lake. Sadler Creek Peninsula is shown by the rectangle, Longpoint Peninsula is shown by the ellipse.

4. Data Analysis

This section of the report discusses the analysis of the bathymetry, velocity and shoreline data. The bathymetry data are compared to the available data from historical surveys. The velocity data are analyzed and presented. The shoreline data are also presented in this section.

4.1. Comparison of Bathymetric Data to Historical Surveys

The new survey data were compared with the historical surveys after the old data were adjusted so that both data sets have the same datum and projection. Also new data sets were corrected for draft. When the data from the high and low frequency transducers were compared, the two results were generally in agreement, except in regions where strong slopes were present. All of the data presented in this section use the 1983 North American Datum (NAD 83) projected by the Universal Transverse Mercator (UTM). The 2003 data plotted in the graphs of this section are from higher frequency depth sounder if otherwise is not stated.

Figure 18 compares the survey results at transect 73. Focusing on the thalweg, up to 1.8 ± 0.27 m of deposition are observed (Figure 19). The estimated uncertainty ($\pm$ 0.27 m) includes potential errors due to digitizing, draft measurement, errors in the old survey, and depth measurement as discussed in section 3.1. A topographic map of transect 73 is shown in Figure 20. Since the detailed coordinates of transects surveyed in 1959 were not provided, exactly same routes of the historical surveys could not be followed at all transects. This is tolerable since the purpose of this study is to investigate where and at what rate the deposition mostly occurred.

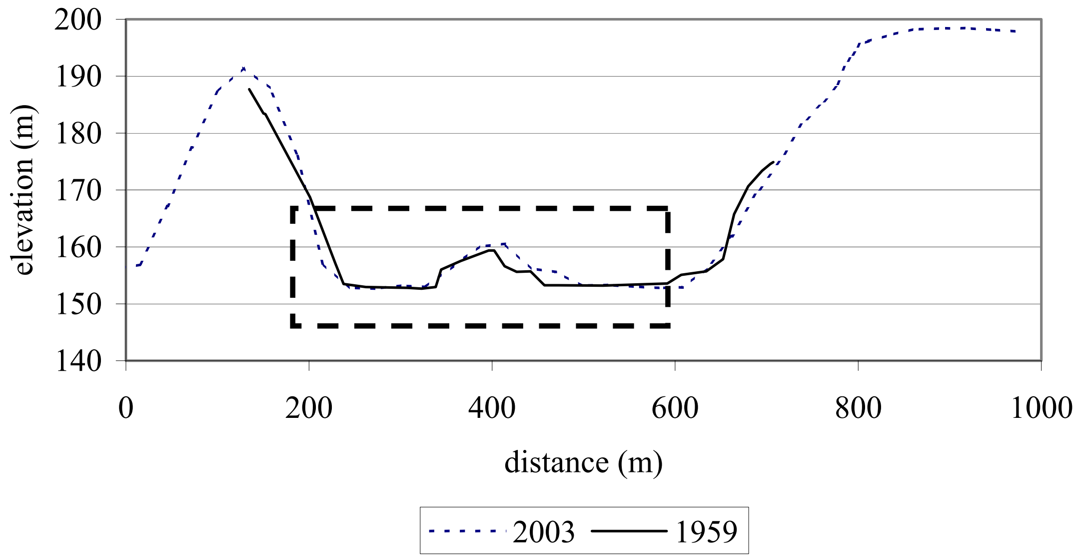


Figure 18. Comparison of survey results at transect 73, with the results of historical survey conducted in 1959. $X = 0$ corresponds to the west end of the transect. Dashed box shows the thalweg of the lake.

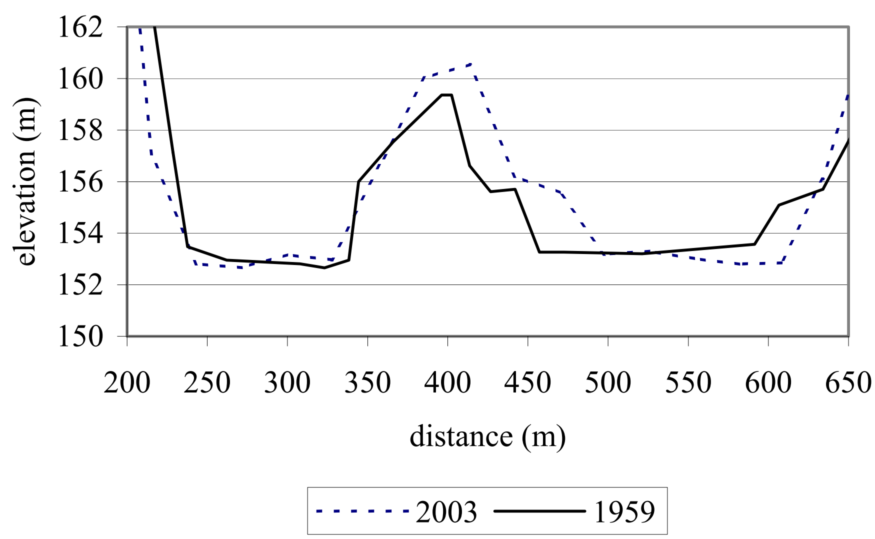


Figure 19. Comparison of survey results within the region shown by the dashed box in Figure 18 with the results of historical survey conducted in 1959.

A resurvey of transect 73 with a different route (shown by 73b in Figure 20) indicated that deviating from the route did not introduce significant errors to the thalweg elevation estimates. The survey results from two different routes are compared in Figure 21.

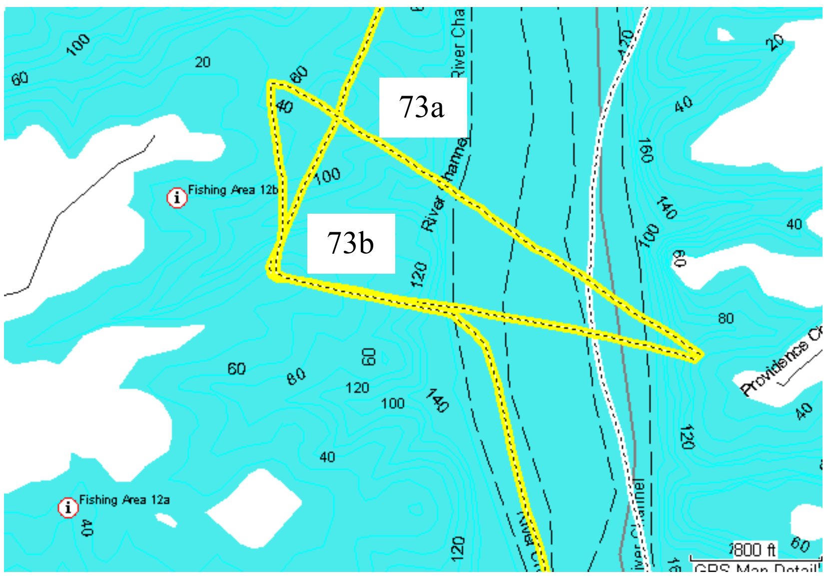


Figure 20. Topography map for transect 73.

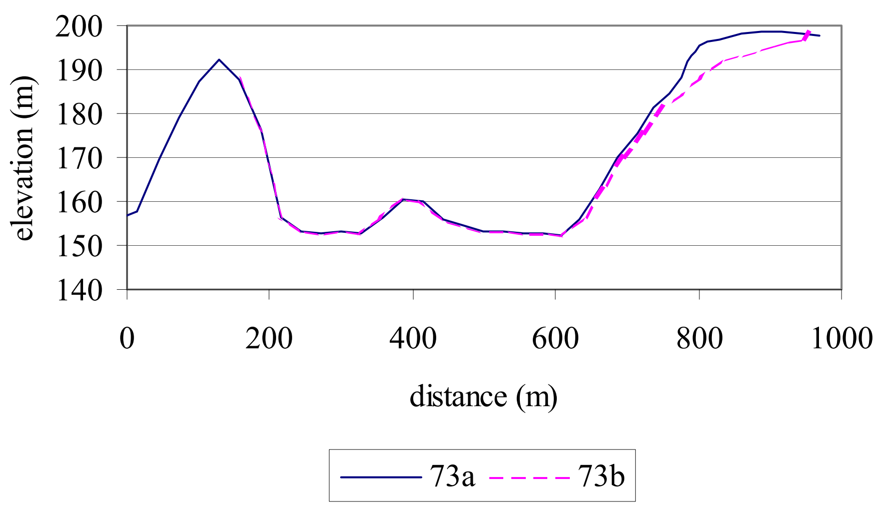


Figure 21. Comparison of surveying results from two different routes shown in Figure 20. $X = 0$ corresponds to the west end of the transect.

Figure 22 compares survey results at transect 74. Within the thalweg, 2 ± 0.27 m of deposition are observed in the deeper regions (Figure 23a). A dashed line is drawn on the topographic map to represent the probable route taken by the surveyors in 1959 (Figure 23b).

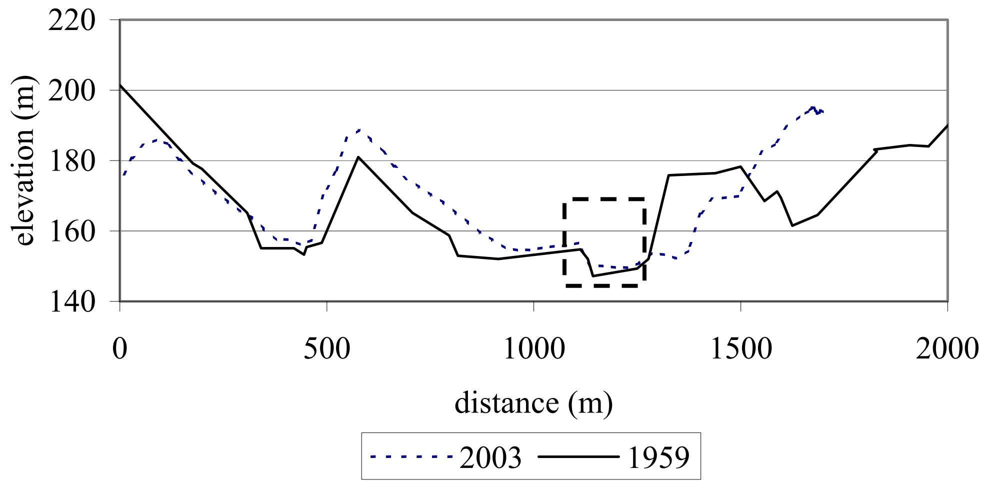
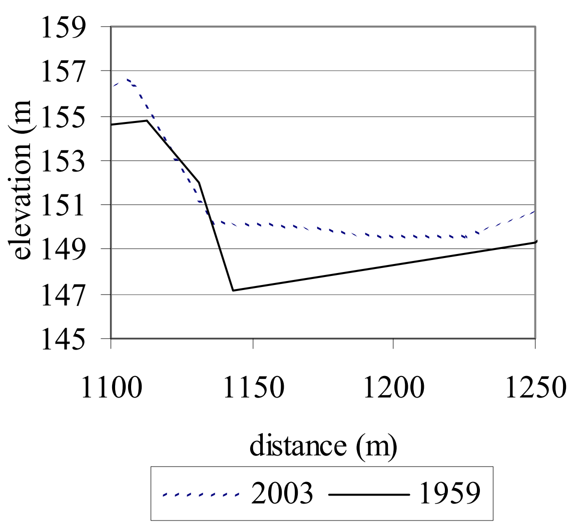


Figure 22. Comparison of survey results at transect 74, with the results of historical survey conducted in 1959. $X = 0$ corresponds to the east end of the transect. Dashed box shows the thalweg of the lake.



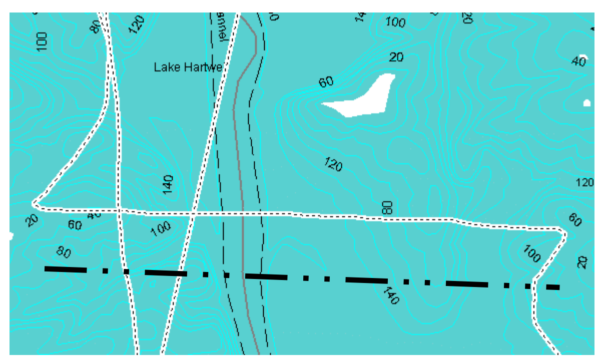


Figure 23. a) Details of survey results shown by dashed line at Figure 22. b) Topography map at transect 74. Dashed line represents the possible route taken in 1959.

Survey results for transect 80 are shown in Figure 24. Similarly, 2 ± 0.27 m of deposition is observed in the thalweg. Details of the survey are given in Figure 25a. The discrepancy between the two surveys at $x =$ 2500 m can be explained by the hill marked by a dashed circle in Figure 25b.

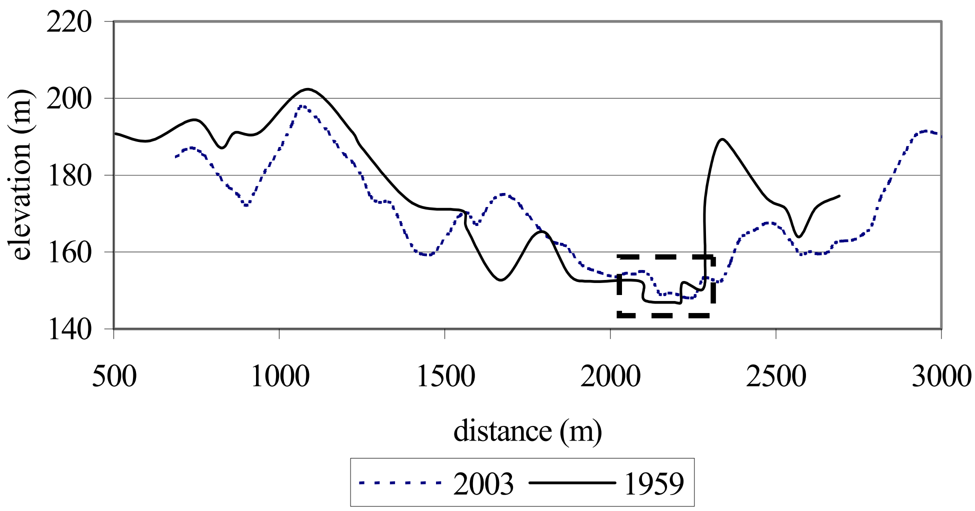


Figure 24. Comparison of survey results at transect 80, with the results of the historical survey conducted in 1959. $X = 0$ corresponds to the east end of the transect. Dashed box shows the thalweg of the lake.

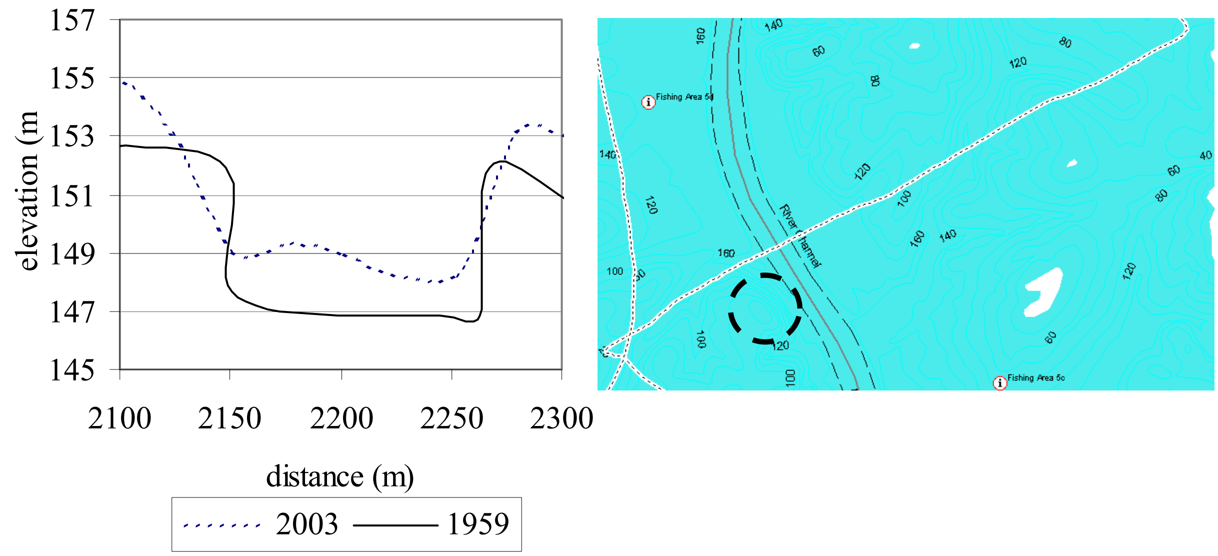


Figure 25. a) Details of survey results shown by dashed line at Figure 24. b) Topography map at transect 80. Dashed eclipse shows the hill that might cause the discrepancy at $x =$ 2500 m.

Transect 81 is the only resurveyed transect that does not pass through the thalweg. The comparison of results with the previous surveys indicated no significant deposition (Figure 26). Details of the deepest region are given in Figure 27a. The differences in the shallow region of the transect ($x \leq$ 1000 m) can be explained by a slight deviation from the route followed by the old survey (see Figure 27b).

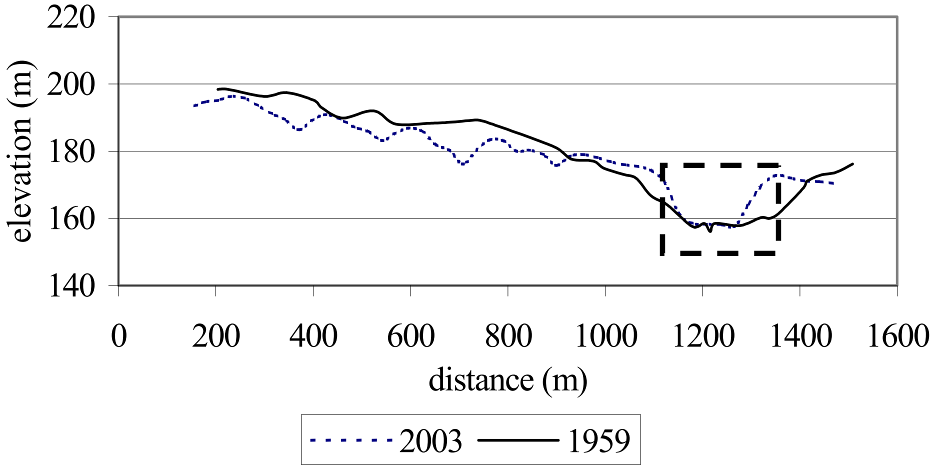


Figure 26. Comparison of survey results at transect 81, with the results of historical survey conducted in 1959. $X = 0$ corresponds to the north end of the transect. Dashed box shows the deepest region of the transect.

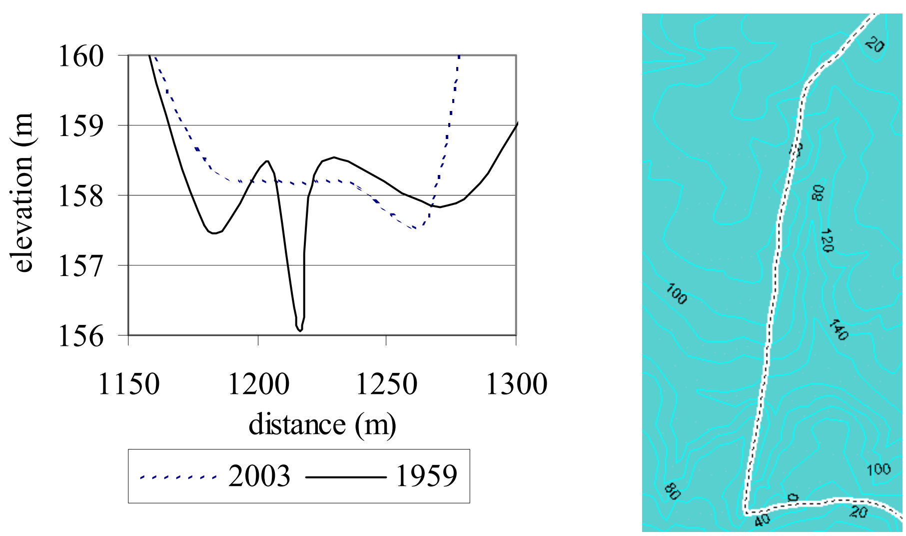


Figure 27. a) Details of survey results shown by dashed line at Figure 26. b) Topography map at transect 81.

Figure 28 shows the comparison of survey results with the previous survey for transect 82. Deposition of 2 ± 0.27 m is observed in the thalweg. Details of the thalweg are given in Figure 29.

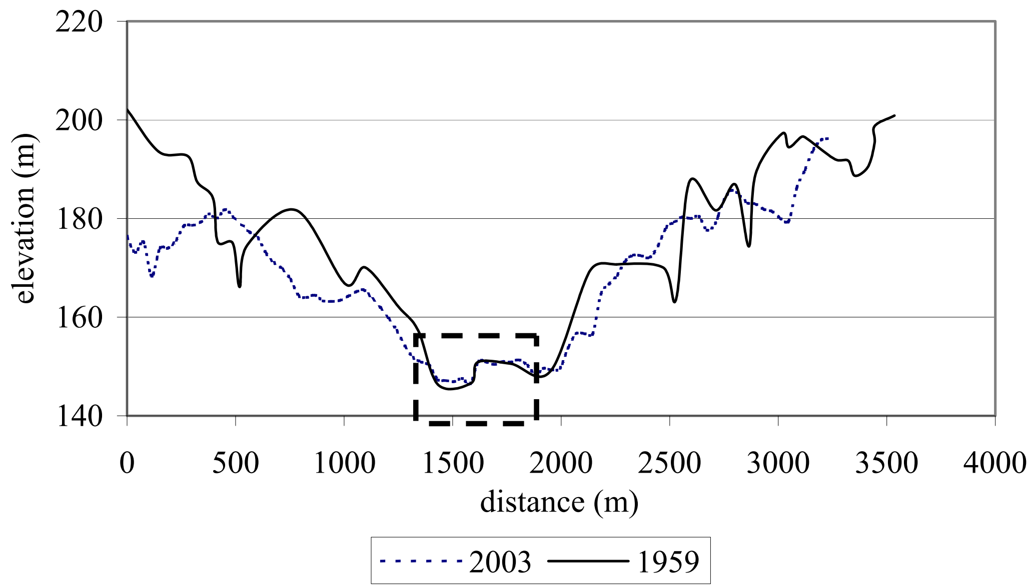


Figure 28. Comparison of survey results at transect 82, with the results of historical survey conducted in 1959. Dashed box shows the thalweg of the lake.

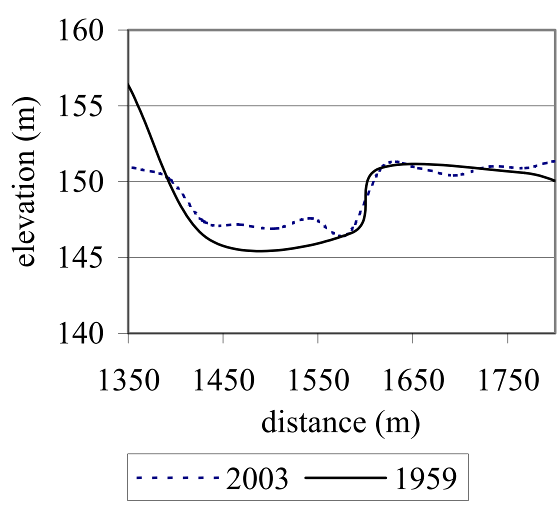


Figure 29. Details of survey results shown by dashed line at Figure 28.

4.2. Analysis of Velocity Data

Velocities at selected transects in Hartwell Lake shown in Figure 15 were measured using the ADCP with GPS speed corrections. During the measurements strong winds from the southwest were observed. Boat speed was maintained near 2.5 m/s.

Figure 30 shows the near-surface velocity vectors measured at transect 1 after correction for boat speed. At this transect maximum surface velocities were measured as 25 cm/s. The measured velocities were filtered to discard measurements for which error velocities exceeded 5 cm/s. Figure 31 shows the measured velocity profile for the same transect before the filtering process. Velocity profiles showing east, north and error velocities captured at an ensemble are given in Figure 32.

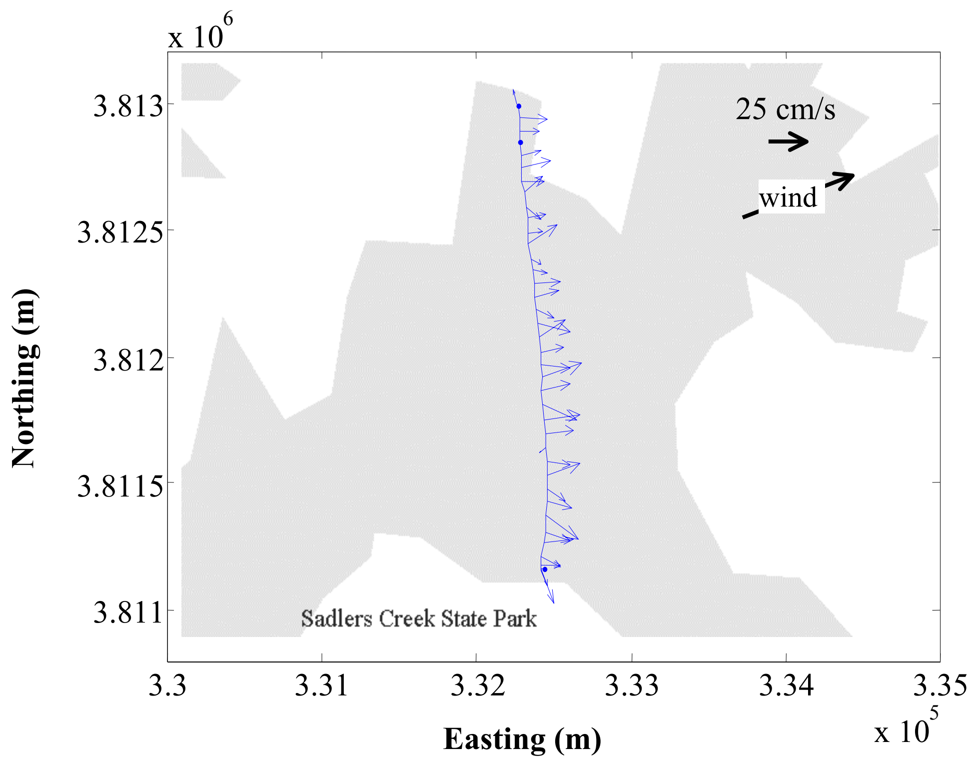


Figure 30. Near-surface velocity vectors measured at transect #1 shown in Figure 15.

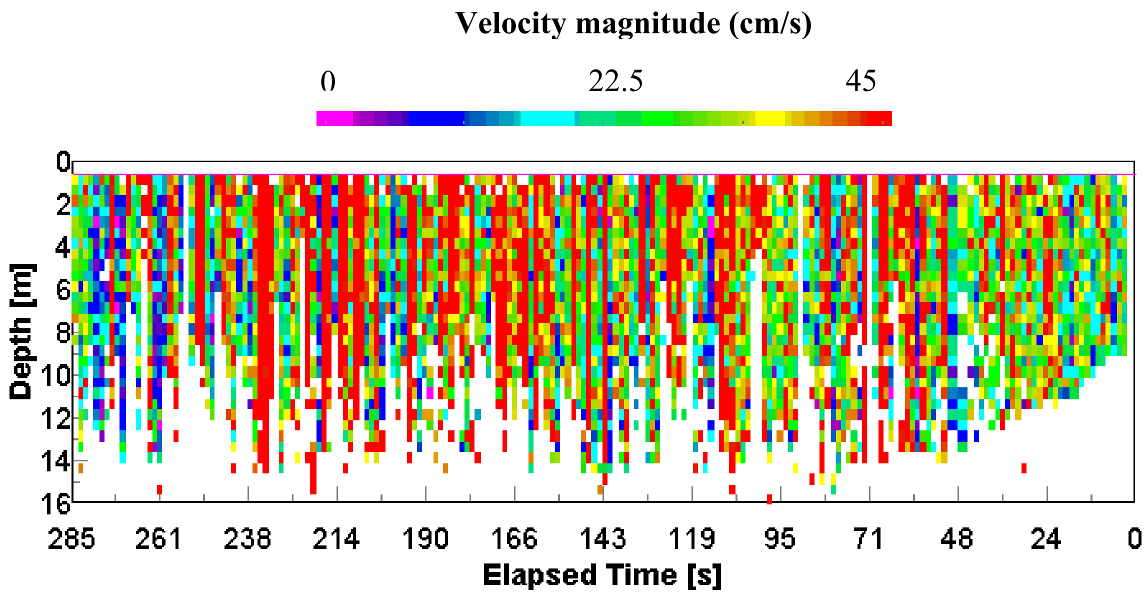


Figure 31. Measured velocity profiles for transect#1.

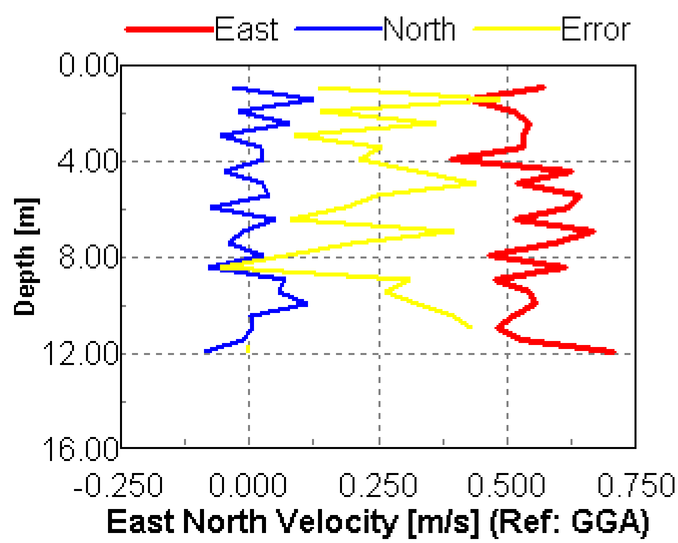


Figure 32. Measured velocity profiles showing east, north and error velocities at an ensemble (*time* = 209 seconds) for transect#1.

Measured near-surface velocities at the other three transects (#2, #3, and #4) are shown in Figures 33, 34 and 35 respectively. In all three cases, maximum measured velocities are ~50 cm/s and average velocities are ~25 cm/s. One rule of thumb for winddriven currents in open water is 3% of wind speed. During the field measurement period wind was blowing from the southwest at ~10 m/s magnitude, which gives roughly 30 cm/s of surface currents in agreement with the measurements.

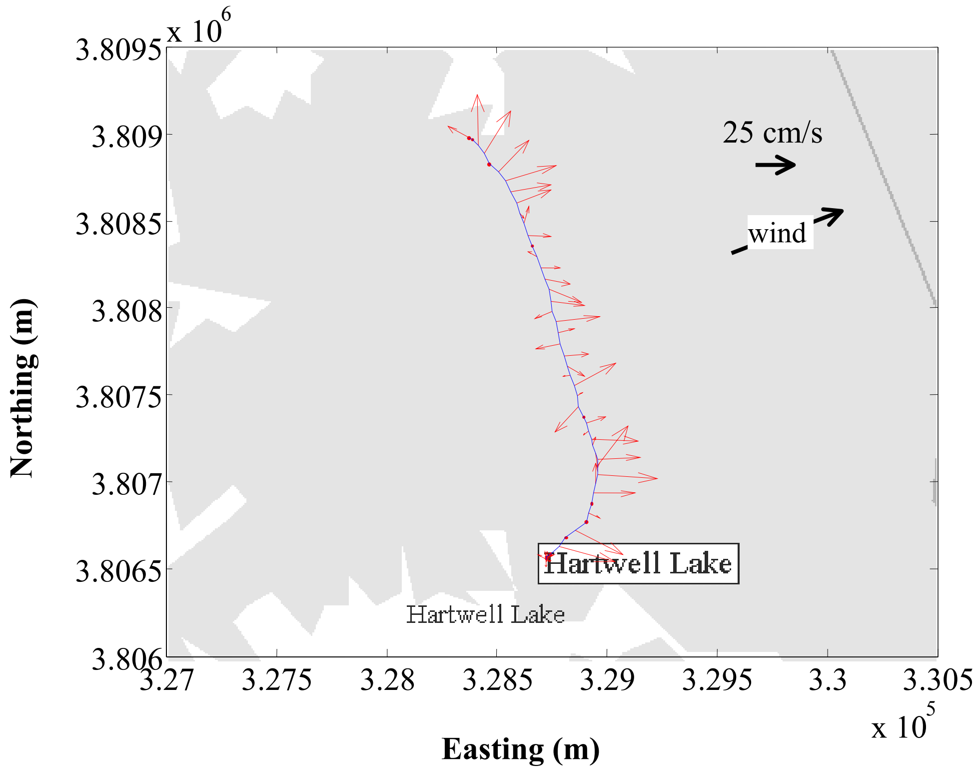


Figure 33. Near-surface velocity vectors measured at transect #2 shown in Figure 15.

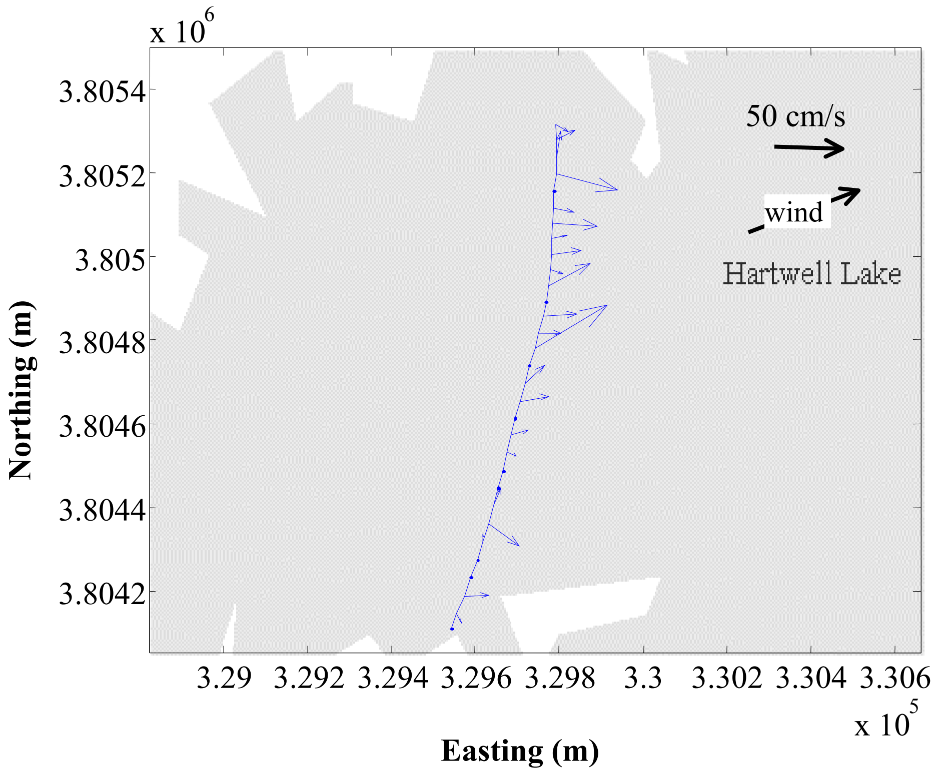


Figure 34. Near-surface velocity vectors measured at transect #3 shown in Figure 15.

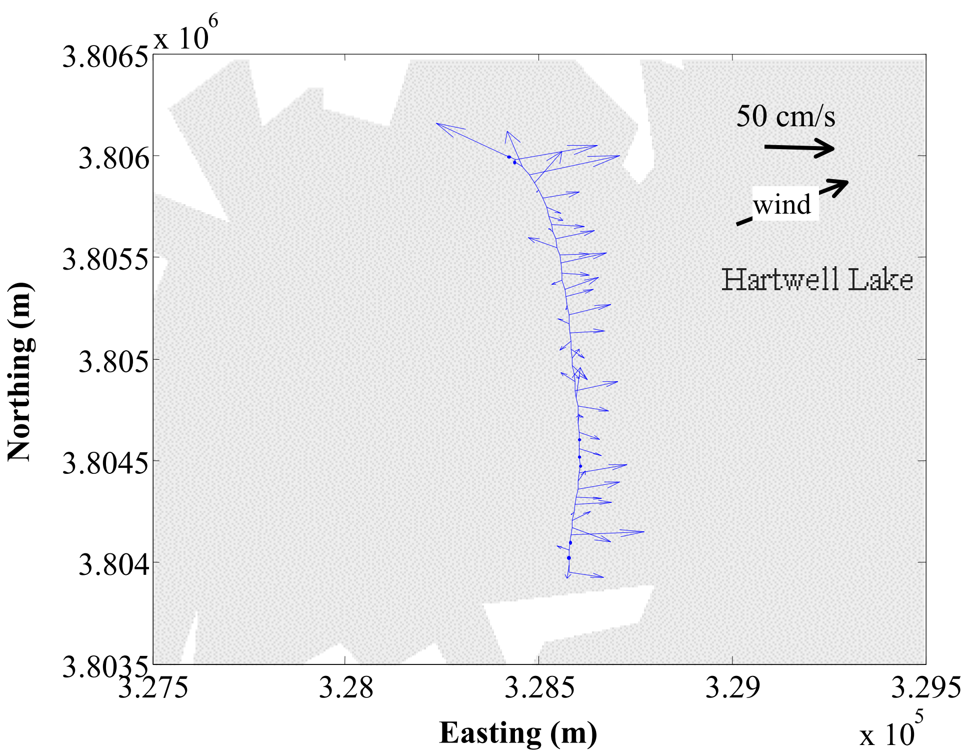


Figure 35. Near-surface velocity vectors measured at transect #4 shown in Figure 15.

Point measurements of velocities were also made at a location shown by (5) in Figure 15. The boat was anchored during the measurement period. Point 5 is located behind Sadler's Creek peninsula and has a small fetch of ~ 500 meters (one tenth of the others). The measured east and north velocities are thus much smaller (about three tenth of the average) than the measured velocities at the four other transects (Figure 36).

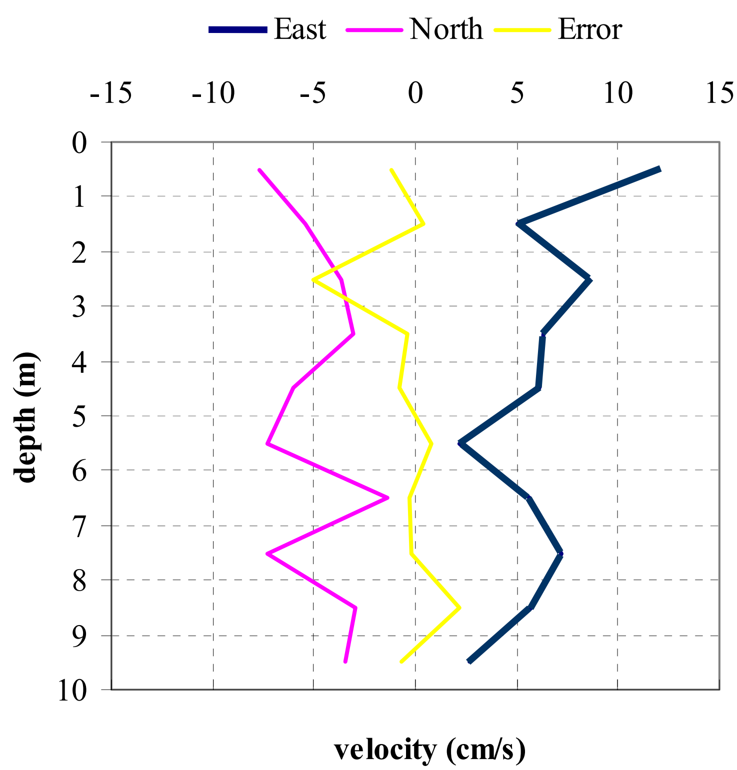


Figure 36. Measured velocity profiles showing east, north and error velocities at point #5 shown in Figure 15.

4.3. Analysis of Shoreline Data

The two peninsulas along the shores of Hartwell Lake, Sadlers Creek and Longpoint Peninsulas, shown in Figure 17 are surveyed. Figure 37 shows the horizontal coordinates of the survey plotted on an aerial photo of the Sadlers Creek Peninsula. The photo was taken on February 25th 1994, and each pixel in the images represents 1 meter × 1 meter of earth. The survey was conducted on February 14th 2003. The mean water levels on both days are given in Table 5. During the surveys both the high water line which is determined where the color changes between the wetted beach and the dry beach, and the low water line, where the shore meets the waters of the lake were followed. Figure 38 shows the 3D geometry of the peninsula. Similarly, horizontal coordinates on an aerial photo of Longpoint Peninsula and 3D geometry of the peninsula are given in Figures 39 and 40 respectively.

Table 5. Comparison of mean water levels during the survey period with the date on which digital aerial photo was taken.

Data	Date	Mean water level
Aerial photo	2/25/94	199.63
Survey	2/14/2003	199.33

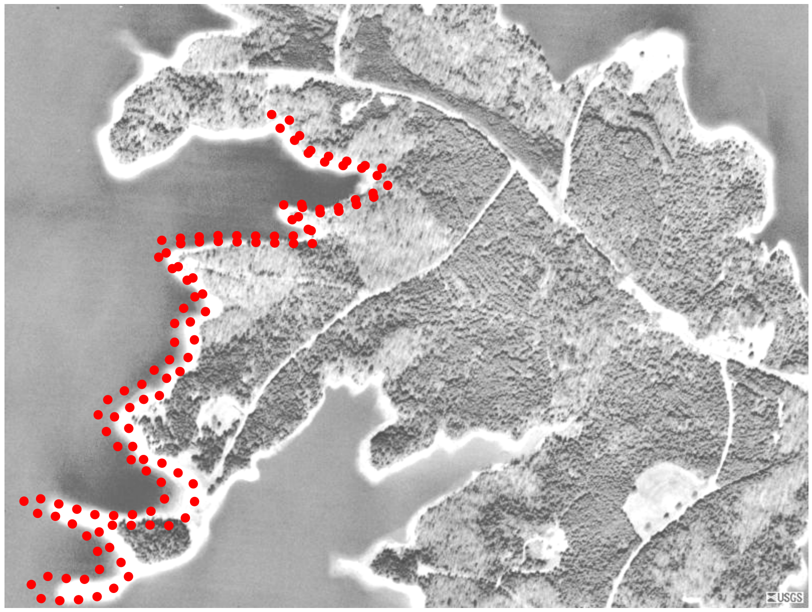


Figure 37. The surveyed transect shown on aerial photo of the Sadlers Creek Peninsula.

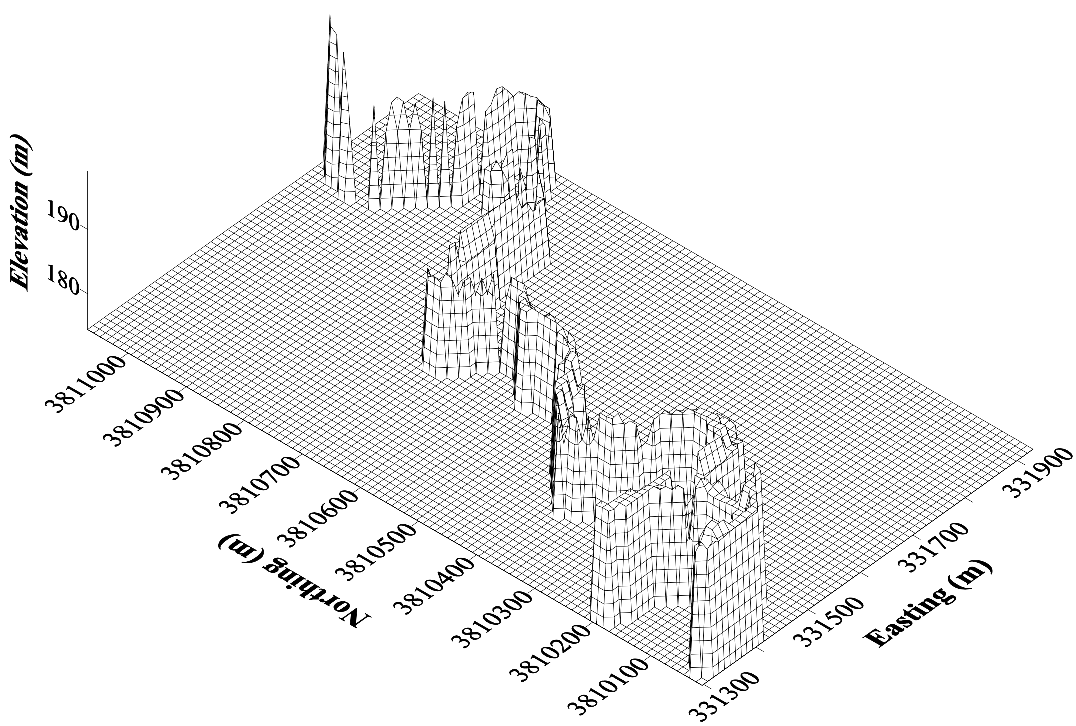


Figure 38. 3D view of the survey results on Sadlers Creek Peninsula.

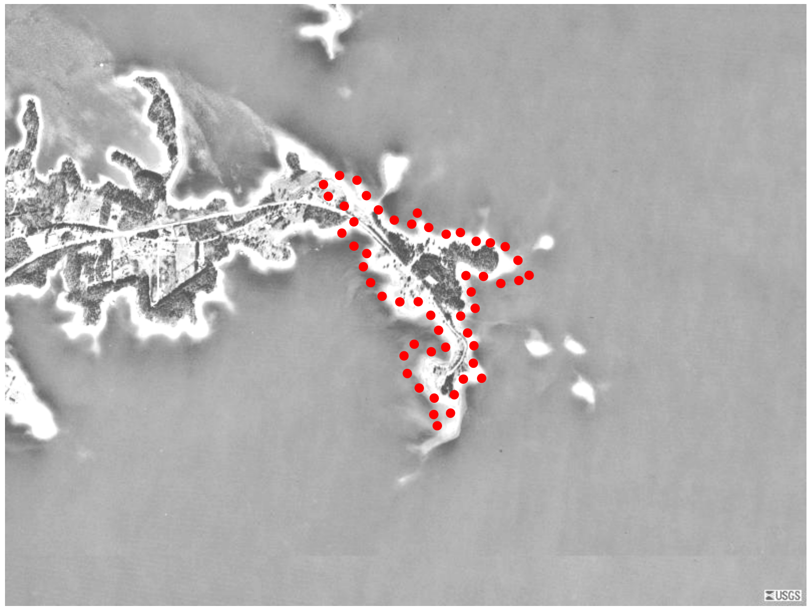


Figure 39. The surveyed transect shown on aerial photo of the Longpoint Peninsula.

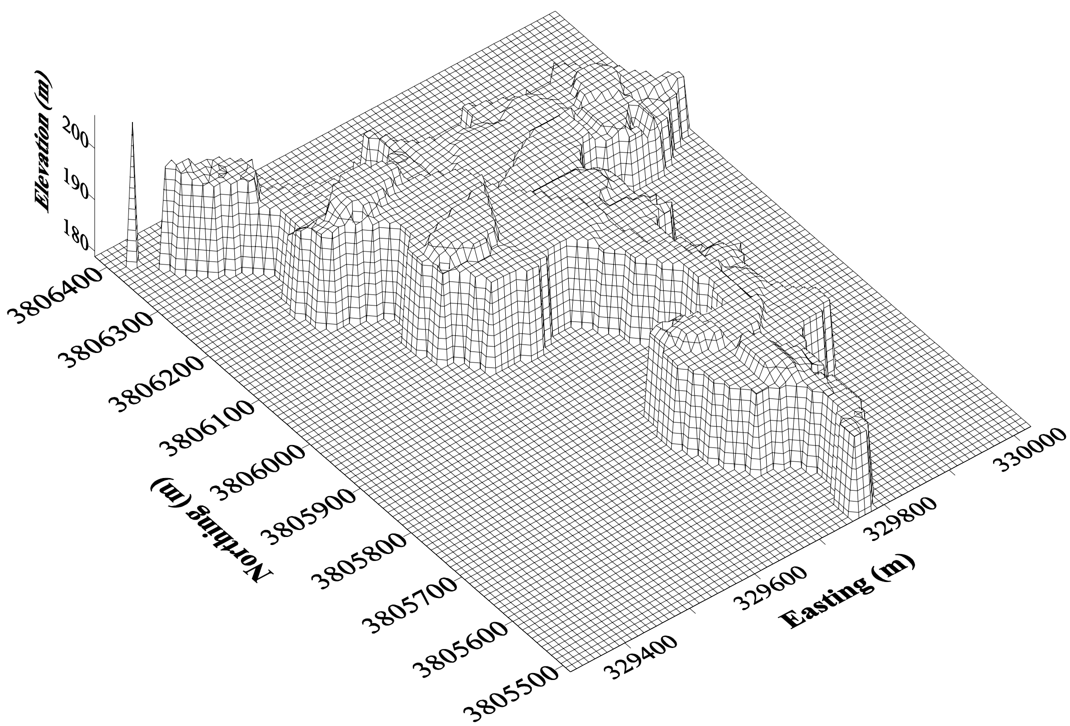


Figure 40. 3D view of the survey results on Longpoint Peninsula.

5. Conclusions

Field data are necessary to provide data for numerical modeling studies and for validation of the results. This report discusses the techniques for data collection in Hartwell Lake and presents the analyzed data. Three types of data were collected in Hartwell Lake between February 10th and February 13th, 2003: bathymetry, velocity and shoreline position data. . Depth data were collected using a dual frequency depth measuring system. Velocity data were measured using a 1200 kHz Acoustic Doppler Current Profiler (ADCP), and shoreline data were provided by a differential global positioning system (GPS). During the bathymetric surveys and velocity measurements a handheld GPS was also integrated with the devices for navigation.

Comparison of bathymetric surveys to previous surveys provided by USACE indicated approximately 2 ± 0.27 meters of deposition over 40 years within the thalweg. The uncertainty arises due to errors in historical surveys, digitizing errors, draft measurement and depth measurement errors. Another main source of error is due to the different routes followed by the authors and the surveyors from USACE. Since the coordinates of old surveys were not available to the authors, exact routes could not be followed. However the interest of the project is deposition at the thalweg, therefore errors due to the deviation from the route are acceptable.

Strong winds (more than 4 times the historical average) from the southwest were observed during the measurement period. Maximum measured surface velocities at several transects were ~50 cm/s and average velocities were ~25 cm/s. The main source of error in measured velocities was due to the boat speed, which calculated by handheld GPS. A ± 6 cm/s error in boat speed thus in water current speed is estimated.

Shoreline data collected at two selected peninsulas are also discussed in this report. The main source of error in the surveys is the precision of GPS (± 10mm).

The data collection techniques and analyzed data for Hartwell Lake are presented in this report. Future work will include simulation of climate and flow conditions in Hartwell Lake for the period of field trip and validation of model results with the measured values. Also, application of the shoreline erosion methodology to the surveyed peninsulas is planned.

6. References

Bruttour, 2003. *Ceestar User Guide for Dual Frequency Digital Survey Echo Sounder*, published by Bruttour International.

Elci, S. and Work, P.A., 2002. Prediction of shoreline erosion and sedimentation in Hartwell Lake, SC/GA. *Technical Report No. GTREP-CEE/2002-1.*

RD Instruments, 2001. *WorkHorse Sentinel User's Guide*, published by the RD Instruments.

Work, P.A., Hansen, M., and Rogers, W.E., 1998. Bathymetric surveying with GPS and heave, pitch, and roll compensation. *J. Surv. Eng., ASCE* , 124(2), 73-90.